

# FLAME SENSOR

## Cross-Reference to Related Application

This Application is related to co-pending U.S. Provisional Patent Application entitled  
5 “Flame Sensor” filed on December 9, 2002 and accorded the Serial No. 60/431,819, which is  
entirely incorporated herein by reference.

## Field of the Invention

The present invention is generally related to a device and method for detecting  
flames.

10

## Background of the Invention

Most fire detection technology for detecting the presence of a flame of burning  
hydrocarbon fuel focuses on detecting heat, smoke (particle matter) or flame (light), i.e., the  
three major characteristics of fire. All of these characteristics also have benign sources other  
than fire, such as heat from steam pipes, particle matter from aerosols, and light from the sun.  
15 Other factors further confound the process of fire detection by masking the characteristic of  
interest, such as air temperature, and air movement. In addition, smoke and heat from fires  
can dissipate too rapidly or accumulate too slowly for effective detection. In contrast,  
because flame sensors are optical devices, they can respond to flames in less than a second.

In an exemplary application, the flame of burning hydrocarbon fuel is the augmentor  
20 flame (afterburner pilot flame) in a gas turbine engine, the loss of which requires an  
automatic engine control to prevent fuel flow to the afterburner; otherwise, dangerous fuel  
levels can accumulate within seconds of the turbine engine losing its ignition flame. Failure

can result in an overpressure condition leading to engine damage. In this scenario, an optical flame sensor is adapted to transmit a flameout condition, which quickly alerts the engine control system to make critical adjustments, e.g., adjusting fuel flow to prevent a potentially catastrophic situation.

5       Optical flame sensors can detect infrared (IR), Ultraviolet (UV), or a combination of UV and IR radiation. A UV flame sensor typically detects radiation emitted in the 200 to 400 nm range. Optical sensing devices incorporating a UV detector to sense the presence of the augmentor flame in gas turbine engines sense UV radiation emitted from the augmentor flame against the background of hot metal, in a high temperature environment and under  
10   heavy vibration.

Disadvantages of UV flame sensors known in the art include the presence of leakage currents and/or parasitic capacitances for a necessary feedback capacitance in the pre-amplifier stage coupled with an inability to survive high temperature operating conditions. For example, not all capacitors that feature a low dissipation factor are rated for high  
15   temperature environments. Also, high temperatures can cause preamplifier input offset errors. Moreover, many UV flame sensors suffer from an insufficient sensitivity to low levels of UV light, due to losses at various components, e.g., the Printed Circuit Board (PCB), feedback capacitor, and amplifier inputs.

#### Summary of the Invention

20       The present invention provides a UV flame sensor that receives optical energy within the UV spectrum and outputs an analog signal proportionate to the intensity of the optical

energy detected, permits operability in high-temperature environments (125°C and higher), and is sensitive to low levels of UV light.

By way of example, a flame sensor consistent with the present invention comprises a housing with associated lensing, electronic circuitry, and an electrical connector. In one embodiment, a flame sensor consistent with the present invention employs a buried capacitance laminate within the PCB to achieve the lowest possible leakage current losses for a necessary feedback capacitance in the pre-amplifier stage. A flame sensor consistent with the present invention employs a PCB routing having carefully-placed tracks, guard bands and ground planes to reduce parasitic capacitance and leakage currents. If desired, a FET may be employed in the pre-amplifier stage for automatic gain control for high signal levels.

#### Brief Description of the Drawings

Figure 1 is a functional block diagram depicting an exemplary detector board and output board consistent with the present invention;

Figure 2 is a schematic illustrating of an exemplary detector board consistent with the present invention;

Figure 3 is a schematic illustrating an alternative embodiment of a detector board consistent with the present invention;

Figure 4 illustrates an exemplary PCB layout of the detector board of Figure 3;

Figure 5 is another illustration of the exemplary PCB layout of the detector board of Figure 3;

Figure 6 is a wiring diagram illustrating the top layer of the exemplary multilayer PCB corresponding to the layout of Figure 5;

Figure 7 is a wiring diagram illustrating the second layer of the exemplary multilayer PCB corresponding to the layout of Figure 5;

Figure 8 is a wiring diagram illustrating the third layer of the exemplary multilayer PCB corresponding to the layout of Figure 5;

5        Figure 9 is a wiring diagram illustrating the bottom layer of the exemplary multilayer PCB corresponding to the layout of Figure 5;

Figure 10 is a layout diagram illustrating the layout of the photodiode on the bottom of the detector board in the exemplary multilayer PCB corresponding to the layout of Figure 5;

10        Figure 11 is an exemplary design specification for the detector board in the exemplary multilayer PCB corresponding to the layout of Figure 5;

Figure 12 is a schematic illustrating an exemplary output board assembly consistent with the present invention;

Figure 13 is an exemplary PCB layout of the output board assembly of Figure 12; and

15        Figures 14-17 are exemplary views of a flame sensor assembly consistent with the invention, including housing, circuitry, and electrical connector.

#### Detailed Description of the Embodiments

With reference now to Figures 1 and 2, in one embodiment, a flame sensor consistent with the present invention comprises a housing with associated lensing, electronic circuitry, and an electrical connector. The electronic circuitry comprises two PCBs: a detector board and an output board.

20

The detector board employs a photodiode 1 to detect the presence of light within the UV spectrum and convert such optical energy into an analog signal proportionate to the intensity of the optical energy detected. As shown in Figure 2, the photodiode is connected to both a virtual ground and the inverting input of operational amplifier 2.

5        Amplifier 2 both amplifies the signal received by the photodiode and changes the current signal output of the photodiode into a voltage signal. The output of the amplifier 2 is connected to the devices that provide the automatic gain control 3, capacitors 20, 21, and 22, which stabilize the signal output from the amplifier 2, and resistor 34 and capacitor 23, which form a low pass filter 4 to reduce the occurrence of noise in the signal output by the detector  
10    board.

The automatic gain control devices 3 form a feedback loop from the amplifier 2 output to the amplifier 2 input, and include a transistor 40, and resistors 30, 31, 32 and 33. When transistor 40 is on, the circuit provides the highest amount of possible gain to the signal from photodiode 1. Likewise, when the transistor is off, the lowest amount of gain to  
15    this signal is provided.

Capacitors 20, 21, and 22 provide stability to the signal output of amplifier 2. These capacitors are formed from a buried capacitance laminate positioned on the inner layers of a multilayer PCB, e.g., as shown in Figures 7 and 8, and together with the placement of guard bands on each of the layers, allow the PCB to achieve the lowest possible leakage current  
20    losses for a necessary feedback capacitance in the Pre-Amplifier stage of the circuit, e.g., as shown in Figure 2. Primarily, these embedded capacitors allow a flame sensor consistent with the instant invention to operate at temperatures for which other types of capacitors with low dissipation factor are not rated.

The layout of the PCB in the instant invention provides several advantages, namely, with respect to the placement of the guard bands 100, the ground planes 101, and the tracks 102. The guard bands are placed in identical positions on each of the layers, and tracks of equal potential are exactly mimicked on the inner layers of the PCB. Thus, the placement of these elements with respect to the various layers, shown in Figures 6, 7, 8, and 9, allows the PCB to minimize any leakage current and to insure that negligible amounts of additional capacitance are introduced into the circuitry.

Figures 1, 12, and 13 illustrate an exemplary output board.

Figures 3, 4, and 5 illustrate other exemplary embodiments of the detector board circuit and layout, and allow for the addition of the elements marked with an asterisk to additionally aid in compensating for any output errors in the circuit.

The exemplary embodiments described above and illustrated in the Figures allow for performance enhancements not found in the prior art. First, the sensor can operate in temperatures as high as 125 degrees Celsius, and is highly sensitive to low levels of UV. While high heat may cause a change in the output of the op-amp, the selection of a low offset op-amp, compensation networks at the input of the op-amp, and the control of the PCB layout to reduce differentials between op amp-inputs, effectively diminishes any reduced circuit performance due to heat. Further, high sensitivity in the circuit is effectuated via the placement of the guard bands and ground planes and the use of buried capacitance.

Furthermore, by using laminate capacitors, recognizing the desire to achieve the smallest RC time constant possible while still maintaining device stability, and using great care in the layout to minimize stray capacitive losses, improved response speed to a change in flame status can be achieved. The response speed of a flame sensor is an important factor

in the detection of the lean blowout oscillatory behavior of a flame. Lean blowout behavior is defined as the point in which the ratio of the amount of air supplied to the amount of fuel supplied is so large that a self-sustaining combustion process can no longer continue. When lean blowout behavior exists, a certain oscillatory signature of the flame can be detected.

5 The detection of the signature could prevent flashback, which can be harmful to combustion equipment.

Figures 14-17 are exemplary views of a flame sensor assembly consistent with the invention, including housing, circuitry, and electrical connector.

Although the present invention has been set forth in terms of the embodiments  
10 described herein, it is to be understood that such disclosure is purely illustrative and is not to be interpreted as limiting. Consequently, without departing from the spirit and scope of the invention, various alterations, modifications, and/or alternative applications of the invention will, no doubt, be suggested to those skilled in the art after having read the preceding disclosure. Accordingly, it is intended that the present invention be interpreted as  
15 encompassing all alterations, modifications, or alternative applications as fall within the true spirit and scope of the invention.